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भारतीय मानक

बाल स्क्रू

भाग 3 स्वीकरण स्थितियाँ और स्वीकरण परीक्षण

Indian Standard

BALL SCREWS

PART 3 ACCEPTANCE CONDITIONS AND ACCEPTANCE TESTS

ICS 25.060.99

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

September 2000

Price Group 9

Machine Tool Elements and Holding Devices Sectional Committee, BP 02

NATIONAL FOREWORD

This Indian Standard (Part 3) which is identical with ISO 3408-3:1992 'Ball screws — Part 3 : Acceptance conditions and acceptance tests' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Machine Tool Elements and Holding Devices Sectional Committee and approval of the Basic and Production Engineering Division Council.

This standard deals with ball screws used on machine tools and is being issued in the following parts:

Ball Screws —

Part 1	Vocabulary and designation
Part 2	Nominal diameters and nominal leads — Metric series
Part 3	Acceptance conditions and acceptance tests
Part 4	Ball screw axial rigidity
Part 5	Distribution of static and dynamic loads and operational life

At the moment, only standards on Parts 1, 2 and 3 are being issued whereas standards in regard to Parts 4 and 5 will be issued as soon as the work on them is completed at the International level.

The text of the ISO Standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In the adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated.

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 230-1:1986 Acceptance code for machine tools—Part 1 : Geometric accuracy of machines operating under no-load or finishing conditions	IS 2063 : 1988 Acceptance code for machine tools — Geometric accuracy of machines operating under no-load or finishing conditions (*first revision*)	Identical
ISO 286-2:1988 ISO system of limits and fits — Part 2 : Tables of standard tolerance grades and limit deviations for holes and shafts	IS 919 (Part 2) : 1993 ISO systems of limits and fits : Part 2 Tables of standard grades and limit deviations for holes and shafts (*first revision*)	do
ISO 3408-1:1991 Ball screws — Part 1 : Vocabulary and designation (*Bilingual edition*)	IS 14872 (Part 1) : 2000 Ball screws Part 1 Vocabulary and designation	do

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard
BALL SCREWS

PART 3 ACCEPTANCE CONDITIONS AND ACCEPTANCE TESTS

1 Scope

This part of ISO 3408 specifies the technical acceptance conditions for ball screws (see figure 1) and, in particular, the respective permissible deviations for the acceptance tests.

NOTE — The actual design need not necessarily correspond to that shown in figure 1.

The respective tests required shall be agreed upon between the manufacturer and the user.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 2308. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 3408 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 230-1 : 1986, *Acceptance code for machine tools — Part 1: Geometric accuracy of machines operating under no-load or finishing conditions.*

ISO 286-2 : 1988, *ISO system of limits and fits — Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts.*

ISO 3408-1 : 1991, *Ball screws — Part 1: Vocabulary and designation.*

3 Definitions

For the purposes of this part of ISO 3408, the definitions given in ISO 3408-1 apply.

4 Test conditions and permissible deviations

4.1 Classification

The tests are graded in five standard tolerance grades (see table 1) in conformance with ISO 286-2 : 1988, table 1.

Table 1 — Standard tolerance grades

Standard tolerance grade 1	↑	Increasing requirements on accuracy and function
Standard tolerance grade 3		
Standard tolerance grade 5		
Standard tolerance grade 7		
Standard tolerance grade 10		

4.2 Geometrical tests

4.2.1 Tolerances

Tolerances on specified travel, e_p, for the useful travel, l_u (tests E1.1 and E1.2), are taken directly from ISO 286-2 : 1988, table 1. Values of e_p for useful travel, l_u, of greater than or equal to 3 150 mm were calculated by linear extrapolation (see table A.1).

Tolerances on travel variation, v_{up}, in micrometres, within the useful travel, l_u, were evaluated using the following equations:

- Grade 1: $v_{up} = 0{,}004\,5\,\bar{l}_u + 4{,}6$
- Grade 3: $v_{up} = 0{,}009\,\bar{l}_u + 9{,}2$
- Grade 5: $v_{up} = 0{,}018\,\bar{l}_u + 18{,}4$

where

$\bar{l}_u$ is the geometrical mean, in millimetres, of the extreme lengths of each step of measured travel given in table A.1:

$$\bar{l}_u = \sqrt{l_{u\,max} \times l_{u\,min}}$$

Run-out tolerances and orientation tolerances were determined from experience.

4.2.2 Travel deviations

Depending on the type of ball screw considered [positioning (type P) or transport (type T) ball screw], the tests given in table 2 shall apply.

The basic measuring principle is illustrated in figure 2.

Table 2 — Travel deviation tests

Travel deviations per reference length	Type of ball screw	
	P	T
	Test	
Travel compensation c for useful travel l_u	Specified by user	$c = 0$
Tolerance on specified travel e_p	E1.1	E1.2
Permissible travel variation v_{up} within useful travel	E2	—
Permissible travel variation v_{300p} within 300 mm travel	E3	E3
Permissible travel variation $v_{2\pi p}$ within 2π rad	E4	—

Tests and tolerances refer to the ball nut body displacement relative to the ball screw shaft.

A pitch-to-pitch measurement may be carried out using a measuring ball by touching the ball track of a non-rotating ball screw shaft. For the measuring intervals, see table A.2.

The travel variation $v_{2\pi}$ within 2π rad is determined over nine measurements (8 × 45°) per revolution or continuously within one thread (at the start, in the middle and at the end of useful travel), provided that this test has been the subject of a special agreement.

4.2.3 Evaluation of the measuring diagrams

To evaluate the actual mean travel deviation within the useful travel, one may use either a mathematical method, which is precise by its very nature, or a graphical method, which is simple and quick and is recommended as an approximation method suitable for everyday evaluations.

NOTE — The travel variation, v_{ua}, resulting from the mathematical method may not be the minimum travel variation.

The graphical method gives the minimum travel variation.

4.2.3.1 Mathematical (least square) method

The actual mean travel deviation, e_a, is given by the formula

$$e_a = a + by$$

with

$$a = \frac{\sum y_i^2 \sum e_i - \sum y_i \sum y_i e_i}{n \sum y_i^2 - \sum y_i \sum y_i}$$

and

$$b = \frac{n \sum \gamma_i e_i - \sum \gamma_i \sum e_i}{n \sum \gamma_i^2 - \sum \gamma_i \sum \gamma_i}$$

where

e_a is the actual mean travel deviation in relation to the specified or nominal travel, as appropriate;

γ is the angle of rotation (specified or nominal travel, as appropriate);

γ_i is the angle of rotation (specified or nominal travel, as appropriate) corresponding to the ith measuring point;

e_i is the travel deviation (or travel) in relation to the specified or nominal travel for the angle of rotation (or travel) corresponding to the ith measuring point;

n is the number of measuring points.

4.2.3.2 Graphical method [see figures 3a) and 3b)]

The evaluation of the actual mean travel deviation from the travel deviation diagram is carried out as follows:

a) draw the tangents to the actual travel deviation curve at two or more upper peaks (l_1, l_2, ...) and repeat this procedure for the lower peaks (l_3, ...);

b) determine the largest respective deviations (e_1, e_2, e_3, ...) parallel to the ordinate, and select from these the smallest deviation (e_2 in the example);

c) draw a straight line through this point of minimum deviation that is parallel to the corresponding peak line (l'_2 parallel to l_2 in the example).

The actual mean travel deviation, e_a, is the centreline between these parallel lines (l_2 and l'_2). The band width within the useful travel, v_{ua}, is the distance between these parallel lines, e_2, measured parallel to the ordinate.

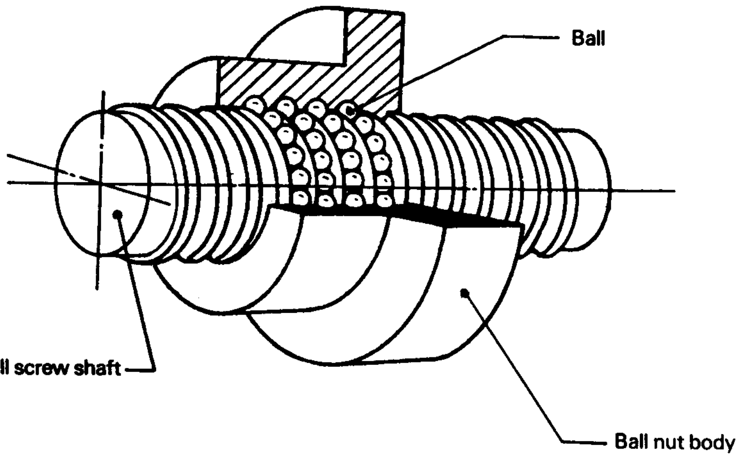


Figure 1 — Ball screw

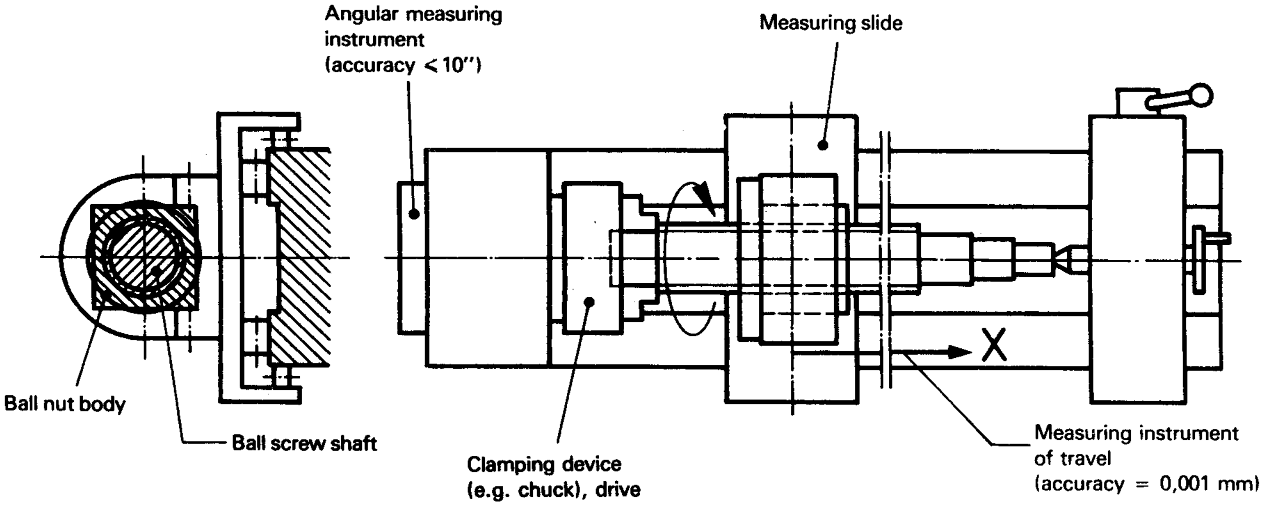
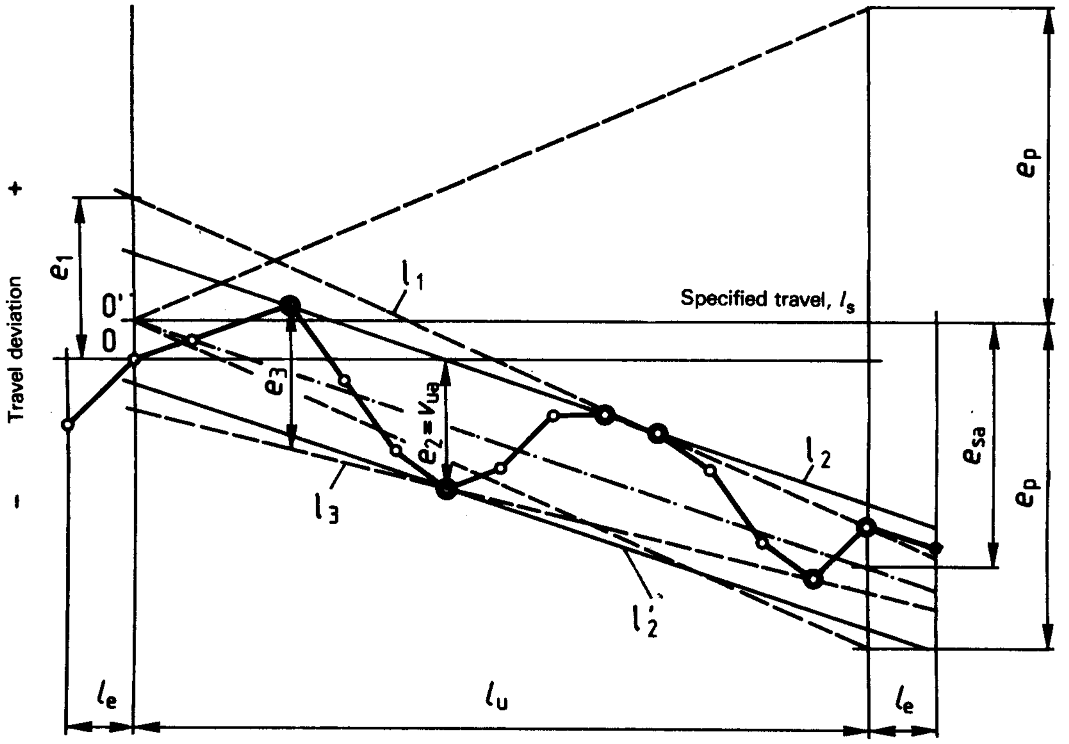
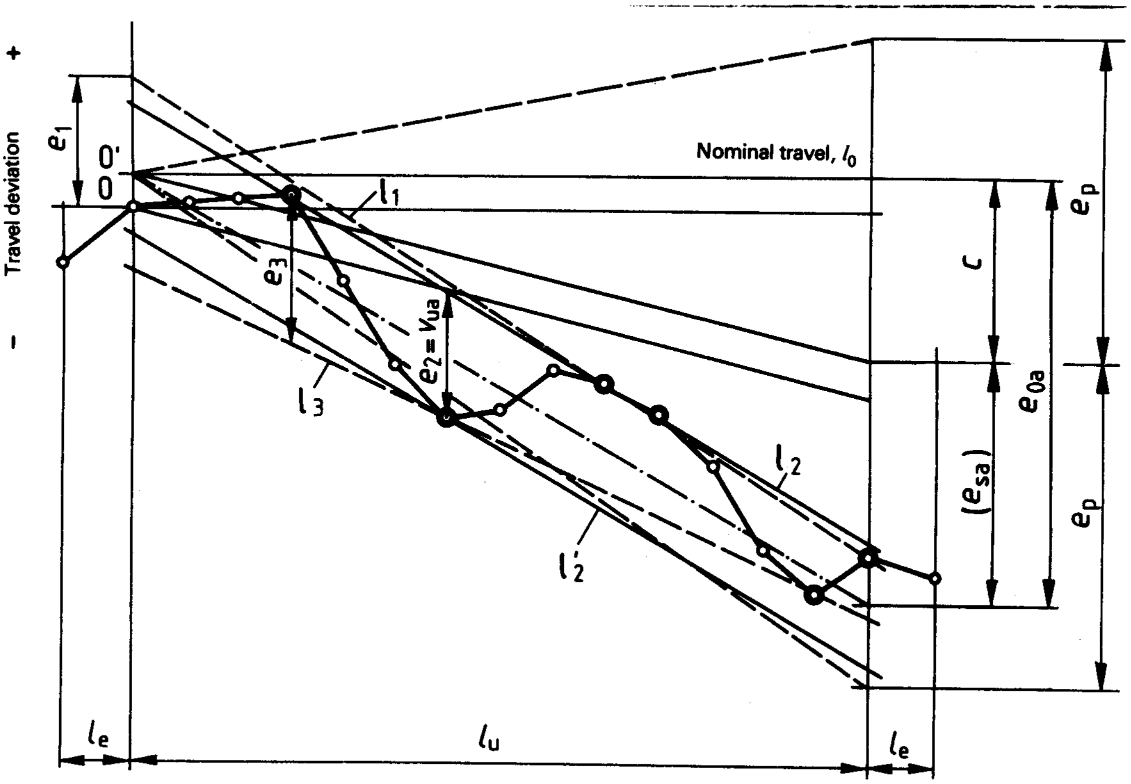

Angular measuring instrument (accuracy < 10″)
Measuring slide
X
Ball nut body
Ball screw shaft
Clamping device (e.g. chuck), drive
Measuring instrument of travel (accuracy = 0,001 mm)

Figure 2 — Basic measuring principle



a) Deviation, e_{sa}, related to the specified travel, l_s



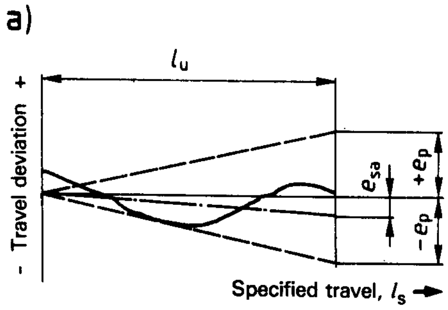
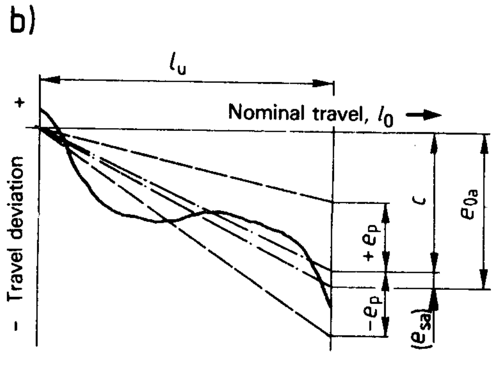
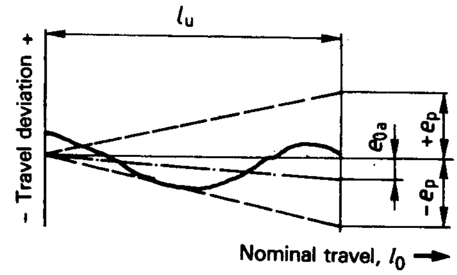
b) Deviation, e_{0a}, related to the nominal travel, l_0

NOTE — For the excess travel, see table A.3.

Figure 3 — Determination of the actual mean travel deviation, e_{sa} or e_{0a}

5 Acceptance tests

5.1 Travel deviation and variation

Test	Diagram	Object	Measuring instruments
E1.1	 a) l_u - Travel deviation + e_{sa} $+e_p$ $-e_p$ Specified travel, l_s  b) l_u Nominal travel, l_0 + - Travel deviation $+e_p$ $-e_p$ c e_{0a} (e_{sa})	Checking of mean travel deviation, e, for useful travel, l_u a) for the specified travel, l_s b) for the nominal travel, l_0	See figure 2
E1.2	 l_u - Travel deviation + e_{0a} $+e_p$ $-e_p$ Nominal travel, l_0	Checking of mean travel deviation, e, for useful travel, l_u	See figure 2

<table>
<tr><th></th><th>Test instruction</th><th>Permissible deviations</th><th>Observations and remarks</th></tr>
<tr><td></td><td>See figure 2</td><td>

Positioning ball screws

<table>
<tr><th colspan="2">l_u
mm</th><th colspan="5">Standard tolerance grade</th></tr>
<tr><th></th><th></th><th>1</th><th>3</th><th>5</th><th>7</th><th>10</th></tr>
<tr><th>above</th><th>up to and including</th><th colspan="5">e_p
µm</th></tr>
<tr><td></td><td>315</td><td>6</td><td>12</td><td>23</td><td>—</td><td>—</td></tr>
<tr><td>315</td><td>400</td><td>7</td><td>13</td><td>25</td><td>—</td><td>—</td></tr>
<tr><td>400</td><td>500</td><td>8</td><td>15</td><td>27</td><td>—</td><td>—</td></tr>
<tr><td>500</td><td>630</td><td>9</td><td>16</td><td>32</td><td>—</td><td>—</td></tr>
<tr><td>630</td><td>800</td><td>10</td><td>18</td><td>36</td><td>—</td><td>—</td></tr>
<tr><td>800</td><td>1 000</td><td>11</td><td>21</td><td>40</td><td>—</td><td>—</td></tr>
<tr><td>1 000</td><td>1 250</td><td>13</td><td>24</td><td>47</td><td>—</td><td>—</td></tr>
<tr><td>1 250</td><td>1 600</td><td>15</td><td>29</td><td>55</td><td>—</td><td>—</td></tr>
<tr><td>1 600</td><td>2 000</td><td>18</td><td>35</td><td>65</td><td>—</td><td>—</td></tr>
<tr><td>2 000</td><td>2 500</td><td>22</td><td>41</td><td>78</td><td>—</td><td>—</td></tr>
<tr><td>2 500</td><td>3 150</td><td>26</td><td>50</td><td>96</td><td>—</td><td>—</td></tr>
<tr><td>3 150</td><td>4 000</td><td>32</td><td>62</td><td>115</td><td>—</td><td>—</td></tr>
<tr><td>4 000</td><td>5 000</td><td>—</td><td>76</td><td>140</td><td>—</td><td>—</td></tr>
<tr><td>5 000</td><td>6 300</td><td>—</td><td>—</td><td>170</td><td>—</td><td>—</td></tr>
</table>

</td><td>

a)

e_{sa} = ... µm

b)

c shall be specified by user

c = ...

e_{0a} = ... µm

</td></tr>
<tr><td></td><td>See figure 2</td><td>

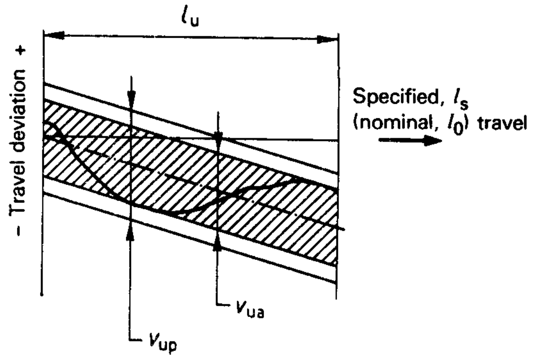
Transport ball screws

<table>
<tr><th colspan="5">Standard tolerance grade</th></tr>
<tr><th>1</th><th>3</th><th>5</th><th>7</th><th>10</th></tr>
<tr><td colspan="5">$c = 0$</td></tr>
<tr><td colspan="5">$e_p = 2 \frac{l_u}{300} v_{300p}$</td></tr>
<tr><td colspan="5">v_{300p}, see test E3</td></tr>
</table>

</td><td>

e_{0a} = ... µm

</td></tr>
</table>

Test	Diagram	Object	Measuring instruments
E2	 l_u + Travel deviation − Specified, l_s (nominal, l_0) travel v_{ua} v_{up}	Checking of travel variation, v_u, within useful travel, l_u	See figure 2

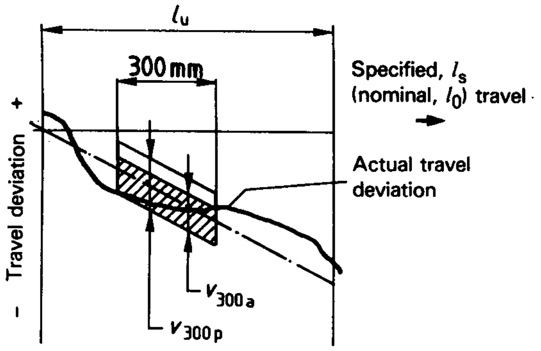
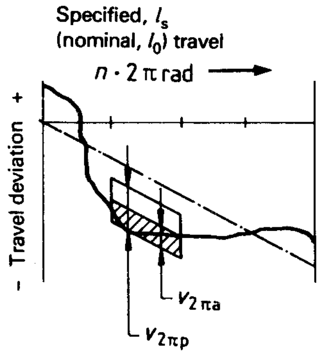
Test instruction	Permissible deviations	Observations and remarks
See figure 2 v_{ua} is the smallest distance, measured parallel to the ordinate, between two lines parallel to the mean travel that envelop the actual travel deviation over the useful travel l_u.	**Positioning ball screws** (table below) **Transport ball screws** (table below)	v_{ua} = ...µm

Positioning ball screws

l_u mm		Standard tolerance grade				
		1	3	5	7	10
above	up to and including	v_{up} µm				
	315	6	12	23	—	—
315	400	6	12	25	—	—
400	500	7	13	26	—	—
500	630	7	14	29	—	—
630	800	8	16	31	—	—
800	1 000	9	17	34	—	—
1 000	1 250	10	19	39	—	—
1 250	1 600	11	22	44	—	—
1 600	2 000	13	25	51	—	—
2 000	2 500	15	29	59	—	—
2 500	3 150	17	34	69	—	—
3 150	4 000	21	41	82	—	—
4 000	5 000	—	49	99	—	—
5 000	6 300	—	—	119	—	—

Transport ball screws

v_{up}
not specified

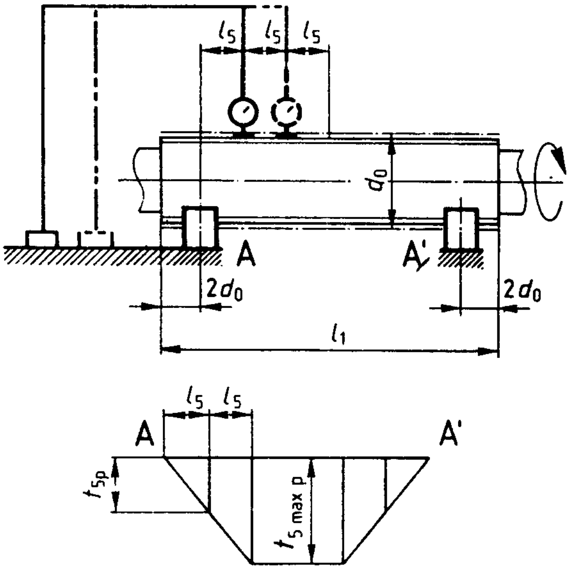
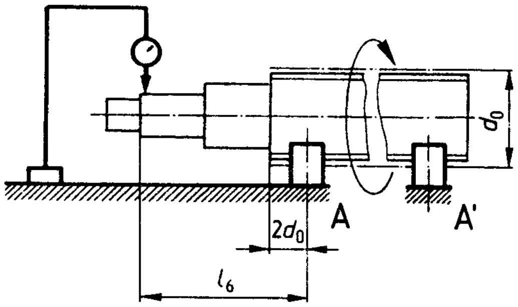
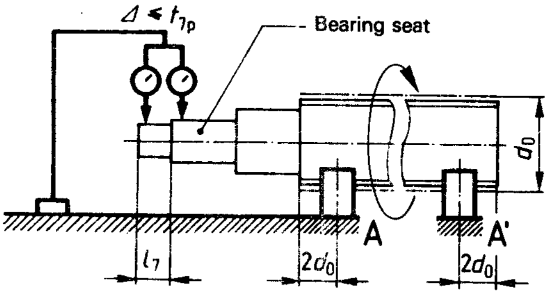
Test	Diagram	Object	Measuring instruments
E3	 l_u 300 mm Specified, l_s (nominal, l_0) travel Actual travel deviation + Travel deviation − v_{300a} v_{300p}	Checking of travel variation, v_{300}, within 300 mm axial travel	See figure 2
E4	 Specified, l_s (nominal, l_0) travel $n \cdot 2\pi$ rad + Travel deviation − $v_{2\pi a}$ $v_{2\pi p}$	Checking of travel variation, $v_{2\pi}$, within 2π rad	See figure 2

<table>
<tr><th></th><th>Test instruction</th><th>Permissible deviations</th><th>Observations and remarks</th></tr>
<tr><td></td><td>See figure 2

v_{300a} is the smallest distance, measured parallel to the ordinate, found when a template is moved along the actual travel deviation and parallel to the mean travel, which contains the actual travel deviation over any 300 mm length along the useful travel.</td><td>Positioning or transport ball screws
<table><tr><th colspan="5">Standard tolerance grade</th></tr><tr><th>1</th><th>3</th><th>5</th><th>7</th><th>10</th></tr><tr><td colspan="5">v_{300p}
µm</td></tr><tr><td>6</td><td>12</td><td>23</td><td>52</td><td>210</td></tr></table></td><td>$v_{300a\,max}$ = ... µm</td></tr>
<tr><td></td><td>See figure 2

$v_{2\pi a}$ is the smallest distance, measured parallel to the ordinate, found when a template is moved along the actual travel deviation and parallel to the mean travel, which contains the actual travel deviation over any distance corresponding to one revolution, i.e. 2π rad along the useful travel.</td><td>Positioning ball screws
<table><tr><th colspan="5">Standard tolerance grade</th></tr><tr><th>1</th><th>3</th><th>5</th><th>7</th><th>10</th></tr><tr><td colspan="5">$v_{2\pi p}$
µm</td></tr><tr><td>4</td><td>6</td><td>8</td><td>–</td><td>–</td></tr></table></td><td>$v_{2\pi a\,max}$ = ... µm</td></tr>
</table>

5.2 Run-out and location tolerances

Test	Diagram	Object	Measuring instruments	
E5	 l_5 l_5 l_5 d_0 A A' $2d_0$ $2d_0$ l_1 l_5 l_5 A A' t_{5p} $t_{5\,max\,p}$	Measurement of radial run-out, t_5, of ball screw shaft outer diameter for ascertaining straightness related to AA' per length l_5	Dial gauge and V-blocks	
E6		Measurement of radial run-out, t_6, of bearing diameter related to AA' per length l for length $l_6 < l$ For length $l_6 > l$ to be valid $t_{6a} < t_{6p} \dfrac{l_6}{l}$	Dial gauge and V-blocks	
E7	 $\Delta \leq t_{7p}$ Bearing seat d_0 A A' l_7 $2d_0$ $2d_0$	Measurement of radial run-out, t_7, of journal diameter related to bearing diameter by determining the difference Δ for $l_7 < l$ For $l_7 > l$ to be valid $t_{7a} < t_{7p} \dfrac{l_7}{l}$	Dial gauge and V-blocks	

Test instruction (Reference to test code ISO 230-1 : 1986)	Permissible deviations	Observations and remarks

Place ball screw on identical V-blocks at points A and A′.

Set dial gauge with measuring shoe at the distance l_5 perpendicular to the cylindrical surface.

Rotate the ball screw slowly and record the changes in the dial gauge reading. Repeat the measurement at specified measuring intervals.

NOTES

1 Optionally, measurement by supporting the ball screw shaft at both centres may be used by agreement.

2 If $l_1 < 2 l_5$, take the measurement at $l_1/2$.

(Clause 5.612.2)

Positioning or transport ball screws

Nominal diameter d_0 mm		l_5 mm	Standard tolerance grade				
			1	3	5	7	10
above	up to and including		t_{5p} for l_5 µm				
6	12	80	20	25	32	40	80
12	25	160					
25	50	315					
50	100	630					
100	200	1 250					

Nominal diameter l_1/d_0		$t_{5\max p}$ for $l_1 > 4\, l_5$ µm				
above	up to and including					
—	40	40	50	64	80	160
40	60	60	75	96	120	240
60	80	100	125	160	200	400
80	100	160	200	256	320	640

t_{5a} = ... µm

$t_{5\max a}$ = ... µm

Place the ball screw at points A and A′ on V-blocks.

Put the dial gauge at the distance l_6 perpendicular to the cylindrical surface.

Rotate the ball screw slowly and record the dial gauge readings.

(Clause 5.612.2)

Positioning or transport ball screws

Nominal diameter d_0 mm		l mm	Standard tolerance grade				
			1	3	5	7	10
above	up to and including		t_{6p} for l µm				
6	20	80	10	12	20	40	63
20	50	125	12	16	25	50	80
50	125	200	16	20	32	63	100
125	200	315	—	25	40	80	125

Diameter	t_{6a} µm
....	....
....	....
....	....
....	....

Place the ball screw at points A and A′ on V-blocks.

Put dial gauges at the distance l_7 perpendicular to the cylindrical surface.

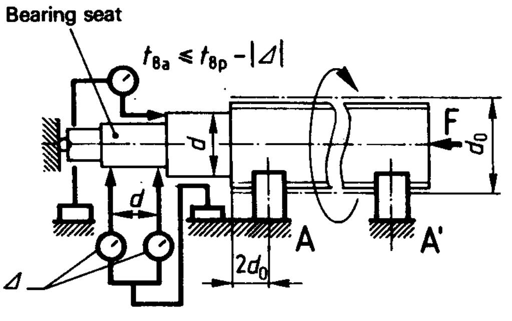
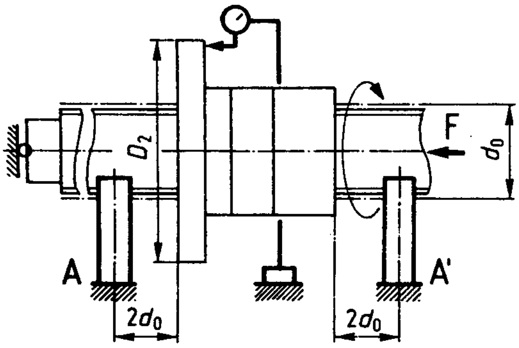
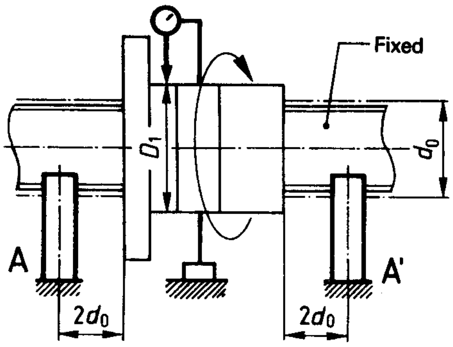
Rotate the ball screw slowly and record the difference in dial gauge readings.

(Clause 5.612.2)

Positioning or transport ball screws

Nominal diameter d_0 mm		l mm	Standard tolerance grade				
			1	3	5	7	10
above	up to and including		t_{7p} for l µm				
6	20	80	5	6	8	12	16
20	50	125	6	8	10	16	20
50	125	200	8	10	12	20	25
125	200	315	—	12	16	25	32

Diameter	t_{7a} µm
....	....
....	....
....	....
....	....

Test	Diagram	Object	Measuring instruments
E8	 Bearing seat $t_{8a} \leqslant t_{8p} - \lvert\Delta\rvert$ F d_0 d d A A' $2d_0$ Δ Δ is the deviation from straightness	Measurement of axial run-out, t_8, of shaft (bearing) faces related to AA'	Dial gauge and V-blocks
E9		Measurement of axial run-out, t_9, of ball nut location face related to AA' (for preloaded ball nuts only)	Dial gauge and V-blocks
E10		Measurement of radial run-out, t_{10}, of ball nut location diameter related to AA' (for preloaded and rotating ball nuts only)	Dial gauge and V-blocks

<table>
<tr><th>Test instruction
(Reference to test code ISO 230-1 : 1986)</th><th>Permissible deviations</th><th>Observations and remarks</th></tr>
<tr><td>Place ball screw at points A and A′ on V-blocks.

Secure the ball screw shaft in the axial direction against movement (e.g. by placing a ball between the centres of the ball screw shaft and the mounting surface).

Place dial gauges perpendicular to the end face of the journal and to the cylindrical surface of the corresponding diameter.

Rotate the ball screw and record the dial gauge readings.

(Clause 5.632)</td>
<td>Positioning or transport ball screws
<table>
<tr><th colspan="2">Nominal diameter
d_0
mm</th><th colspan="5">Standard tolerance grade</th></tr>
<tr><th></th><th></th><th>1</th><th>3</th><th>5</th><th>7</th><th>10</th></tr>
<tr><th>above</th><th>up to and including</th><th colspan="5">t_{8p}
µm</th></tr>
<tr><td>6</td><td>63</td><td>3</td><td>4</td><td>5</td><td>6</td><td>10</td></tr>
<tr><td>63</td><td>125</td><td>4</td><td>5</td><td>6</td><td>8</td><td>12</td></tr>
<tr><td>125</td><td>200</td><td>—</td><td>6</td><td>8</td><td>10</td><td>16</td></tr>
</table></td>
<td><table>
<tr><th>Diameter</th><th>t_{8a}
µm</th></tr>
<tr><td>............</td><td>............</td></tr>
<tr><td>............</td><td>............</td></tr>
<tr><td>............</td><td>............</td></tr>
</table></td></tr>
<tr><td>System preloaded. Place ball screw on V-blocks at points A and A′.

Secure the ball screw shaft in the axial direction against movement (e.g. by placing a ball between the centres of the ball screw shaft and the mounting surface).

Place the dial gauge perpendicular to the flange face at the outer rim of inspection diameter D_2.

Secure the ball nut against rotation on the ball screw shaft.

Rotate the ball screw shaft and record the dial gauge readings.

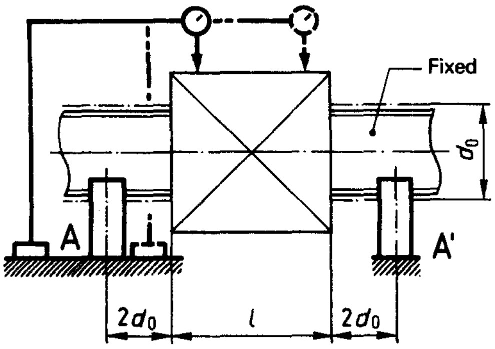
(Clause 5.632)</td>
<td>Positioning or transport ball screws
<table>
<tr><th colspan="2">Flange diameter
D_2
mm</th><th colspan="5">Standard tolerance grade</th></tr>
<tr><th></th><th></th><th>1</th><th>3</th><th>5</th><th>7</th><th>10</th></tr>
<tr><th>above</th><th>up to and including</th><th colspan="5">t_{9p}
µm</th></tr>
<tr><td>16</td><td>32</td><td>10</td><td>12</td><td>16</td><td>20</td><td>—</td></tr>
<tr><td>32</td><td>63</td><td>12</td><td>16</td><td>20</td><td>25</td><td>—</td></tr>
<tr><td>63</td><td>125</td><td>16</td><td>20</td><td>25</td><td>32</td><td>—</td></tr>
<tr><td>125</td><td>250</td><td>20</td><td>25</td><td>32</td><td>40</td><td>—</td></tr>
<tr><td>250</td><td>500</td><td>—</td><td>32</td><td>40</td><td>50</td><td>—</td></tr>
</table></td>
<td>$t_{9a\,max}$ = ... µm</td></tr>
<tr><td>System preloaded. Place ball screw on V-blocks at points A and A′.

Place the dial gauge perpendicular to the cylindrical surface of ball nut location diameter D_1.

Secure the ball screw shaft.

Rotate the ball nut body slowly. Record the dial gauge readings.

(Clause 5.612.2)</td>
<td>Positioning or transport ball screws
<table>
<tr><th colspan="2">Ball nut body outer diameter
D_1
mm</th><th colspan="5">Standard tolerance grade</th></tr>
<tr><th></th><th></th><th>1</th><th>3</th><th>5</th><th>7</th><th>10</th></tr>
<tr><th>above</th><th>up to and including</th><th colspan="5">t_{10p}
µm</th></tr>
<tr><td>16</td><td>32</td><td>10</td><td>12</td><td>16</td><td>20</td><td>—</td></tr>
<tr><td>32</td><td>63</td><td>12</td><td>16</td><td>20</td><td>25</td><td>—</td></tr>
<tr><td>63</td><td>125</td><td>16</td><td>20</td><td>25</td><td>32</td><td>—</td></tr>
<tr><td>125</td><td>250</td><td>20</td><td>25</td><td>32</td><td>40</td><td>—</td></tr>
<tr><td>250</td><td>500</td><td>—</td><td>32</td><td>40</td><td>50</td><td>—</td></tr>
</table></td>
<td>$t_{10a\,max}$ = ... µm</td></tr>
</table>

Test	Diagram	Object	Measuring instruments
E11		Deviation of parallelism, t_{11}, of rectangular ball nut related to AA' (for preloaded ball nuts only)	Dial gauge and V-blocks

<table>
<tr><th>Test instruction
(Reference to test code
ISO 230-1 : 1986)</th><th>Permissible deviations</th><th>Observations
and remarks</th></tr>
<tr><td>System preloaded.

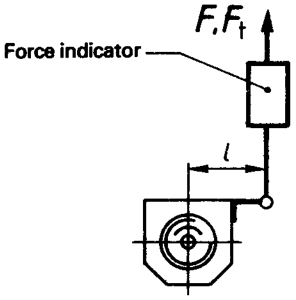
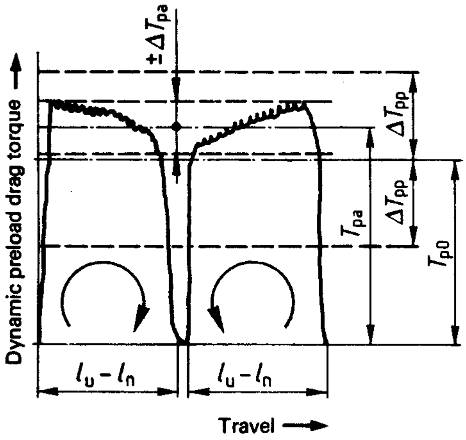
Place ball screw on V-blocks at points A and A′.

Place the dial gauge perpendicular to the inspection surface and probe along the specified inspection length l.

Record the dial gauge readings.

(Clause 5.412.2)</td><td>Positioning or transport
ball screws
<table>
<tr><th colspan="5">Standard tolerance grade</th></tr>
<tr><th>1</th><th>3</th><th>5</th><th>7</th><th>10</th></tr>
<tr><td colspan="5">t_{11p} for each 100 mm
(cumulative)
µm</td></tr>
<tr><td>16</td><td>20</td><td>25</td><td>32</td><td>–</td></tr>
</table></td><td>$t_{11a\,max}$ = ... µm</td></tr>
</table>

5.3 Functional tests

Test	Diagram	Object	Measuring instruments
E12	 $T_p = F \cdot l$ without end seals $T_p = F_t \cdot l$ with end seals  l_n = ball nut length	Measurement of tolerance on dynamic preloaded drag torque, ΔT_p	Test bench with recorder for force value measured

Test instruction	Permissible deviations	Observations and remarks

System preloaded (with or without end seals).

For the recording of the radial preload force, couple the ball nut body to a load cell at the distance l from the axis of rotation.

Take recordings at a rotational speed of 100 min^{-1} in both directions of rotation.

For lubrication, use a lubricant of ISO viscosity grade 100.[1)]

Positioning or transport ball screws

T_{p0} Nm		Standard tolerance grade				
		1	3	5	7	10
above	up to and including	For $l_u/d_0 < 40$; $l_u < 4\,000$ mm ΔT_{pp} % of T_{p0}				
0,2	0,4	35	40	50	—	—
0,4	0,6	30	35	40	—	—
0,6	1	25	30	35	40	—
1	2,5	20	25	30	35	—
2,5	6,3	15	20	25	30	—
6,3	10	—	15	20	30	—
T_{p0} Nm		For $l_u/d_0 < 60$; $l_u < 4\,000$ mm ΔT_{pp} % of T_{p0}				
above	up to and including					
0,2	0,4	40	50	60	—	—
0,4	0,6	35	40	45	—	—
0,6	1	30	35	40	45	—
1	2,5	25	30	35	40	—
2,5	6,3	20	25	30	35	—
6,3	10	—	20	25	35	—
T_{p0} Nm		For $l_u > 4\,000$ mm ΔT_{pp} % of T_{p0}				
above	up to and including					
	0,6		not specified			
0,6	1	—	40	45	50	—
1	2,5	—	35	40	45	—
2,5	6,3	—	30	35	40	—
6,3	10	—	25	30	35	—

Without end seals

l = ... m

F = ... N

T_{pa} = ... Nm

ΔT_{pa} = ± .... Nm

≙ ± .... % of T_{p0}

With end seals

F_t = ... N

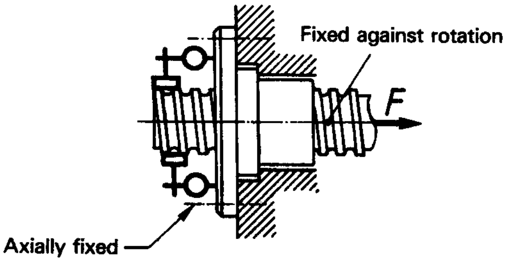
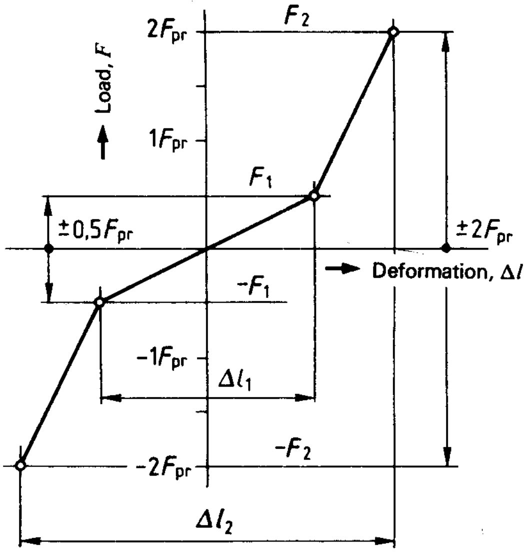
T_{ta} = ... Nm

ΔT_{ta} = ± .... Nm

≙ ± .... % of T_{p0}

---

1) Other rotational speeds, lubricants and measuring instruments may be used by agreement between the user and the manufacturer.

Test	Diagram	Object	Measuring instruments
E13	  	Measurement of axial rigidity, R_{nu}	Dial gauges and load cell

Test instruction	Observations and remarks
Fix preloaded ball nut axially in both directions and secure ball screw shaft against rotation. Place dial gauge supports on the ball screw shaft and touch the measuring stylus against the face of the ball nut body, as near as possible and as parallel as possible to the ball screw shaft axis. Apply axial loads $F_1 = 0{,}5F_{\mathrm{pr}}$ or $F_2 = 2F_{\mathrm{pr}}$ to the ball screw shaft in tension and in compression. F_{pr} is the preload and Δl_1 or Δl_2 are the elastic deformations (reversal range) caused by the axial test loads $\pm F_1$ or $\pm F_2$ respectively. Rigidity in the range $\pm F_1$: $R_{\mathrm{nu1}} = \frac{2F_1}{\Delta l_1} = \frac{F_{\mathrm{pr}}}{\Delta l_1}$ Rigidity in the range $+F_1$ to $+F_2$ and $-F_1$ to $-F_2$: $R_{\mathrm{nu2}} = \frac{2(F_2 - F_1)}{\Delta l_2 - \Delta l_1} = \frac{3F_{\mathrm{pr}}}{\Delta l_2 - \Delta l_1}$ Other test loads F may be used by agreement between the user and the manufacturer.	F_{pr} = ... N F_1 = ... N F_2 = ... N Δl_1 = ... µm Δl_2 = ... µm R_{nu1} = ... N/µm R_{nu2} = ... N/µm

Annex A
(normative)

Complementary tables

Table A.1 — Tolerance values on specified travel, e_p, for a band width per 300 mm (v_{300}) and for a mean travel deviation, e, and for the standard tolerance grades according to ISO 286-2 : 1988

Measured travel mm		Standard tolerance grade				
		1	3	5	7	10
above	up to and including	Tolerance on specified travel, e_p µm				
—	315	6	12	23	52	210
315	400	7	13	25	57	230
400	500	8	15	27	63	250
500	630	9	16	32	70	280
630	800	10	18	36	80	320
800	1 000	11	21	40	90	360
1 000	1 250	13	24	47	105	420
1 250	1 600	15	29	55	125	500
1 600	2 000	18	35	65	150	600
2 000	2 500	22	41	78	175	700
2 500	3 150	26	50	96	210	860
3 150	4 000	32*)	62*)	115*)	260*)	1 050*)
4 000	5 000	39*)	76*)	140*)	320*)	1 300*)
5 000	6 300	48*)	92*)	170*)	390*)	1 550*)

*) These values were calculated by linear extrapolation from the IT values in accordance with ISO 286-2 for sizes above 500 mm and less than or equal to 3 150 mm.

Table A.2 — Minimum number of measurements over 300 mm (measuring intervals)

Lead P_h mm	Specified tolerance grade				
	1	3	5	7	10
	Minimum number of measurements				
2,5	15	10	6	3	1
5	15	10	6	3	1
10	10	5	3	1	1
20	5	4	3	1	1
40	—	2	1	1	1

Table A.3 — Maximum excess travel

Dimensions in millimetres

Lead P_h	2,5	5	10	20	40
Maximum excess travel $l_{e\,max}$	10	20	40	60	100

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